CHAPTER 2

Biodiversity: Issues and Implications

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Importance of Biodiversity

BIODIVERSITY: ISSUES & IMPLICATIONS

iodiversity is a shortened form of the term *biological diversity*[1]—the spectrum of life forms and the ecological processes that support and sustain them. Biodiversity supports the integrity of the ecological systems upon which humans depend. These ecological systems (*ecosystems*) are self-sustaining units, and to a certain extent they can absorb disturbance without suffering loss of function. However, repeated or large-scale human disturbance inevitably changes ecosystems and can threaten their viability.

Biological diversity—or biodiversity "for short"—is the spectrum of life forms and the ecological processes that support and sustain them.

Humans have a profound and continuing impact on Wisconsin's ecological systems. While some may think of tropical rainforests as the only areas where ecosystems are in danger, continuing human population growth here at home creates pressures on our natural communities. Human population growth, coupled with land development patterns and high per-capita consumption of energy and natural resources, leads to pressure on habitat from development, air and water pollution, and extraction of resources for energy and other uses. All of this can lead to loss of biological diversity.

As human populations grow and our needs and ability to use the environment increase, we will continue to alter ecological systems even though the absolute limits of ecological systems to absorb human activities are unknown. At the same time, we depend on these systems for clean air and water, food, shelter, and the raw materials that support many of Wisconsin's industries. In addition to these benefits, plants have yielded life-saving drugs, and studies of animals have provided valuable insight into navigation, biochemistry, linguistics, and medicine. Conserving biodiversity will help sustain the ecological systems that we depend on. It will also preserve options for future decision-making.

Biodiversity is complicated, occurring at many different levels. For purposes of study and management, biological diversity is usually grouped into four levels: *genetic diversity, species diversity, community diversity*, and *ecosystem diversity* (Fig. 1).

Genetic diversity consists of the spectrum of genetic material carried by different organisms. Genetic diversity within a population of a plant or animal species has the potential to change over time, allowing species to adapt to environmental conditions and retain vigor. Although genetic diversity may be expressed in visible characteristics, such as color, size, and shape, much is expressed in biochemical processes that are hidden from view. Individuals within a population carry a variety of genes. If something happens to reduce the size or variety of the gene pool, then that population's genetic diversity is compromised.

Species diversity results from the variety of *species* in a geographic area. It includes not only the number of species in

[1] Terms in italics are defined in the glossary.

Genetic Diversity

The variation in genetic composition of individuals within and among species. (e.g. variation within a population of rabbits)

Species Diversity

The variety of different species found in an area. (e.g. the variety of species found in a prairie)

Community and Ecosystem Diversity

The variety of physical environments and biotic communities over a landscape. (e.g., the variety of forests, grasslands, wetlands and aquatic systems over a region)

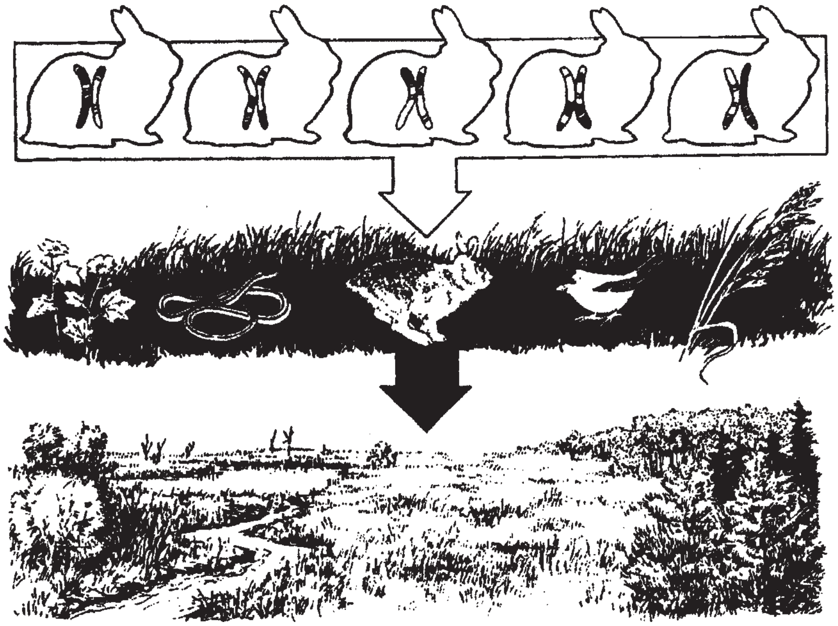


Figure 1

Biological diversity occurs at four interrelated levels, adapted from Temple (1991).

the area but also their relative abundance and spatial distribution. Species are the most familiar level of diversity because they can be classified and counted, and many, though not all, are readily visible. Species include everything from soil fungi and insects to eagles and deer, from darters to muskies, and from mosses and lichens to hemlock and red pine. Every species has a niche, or a role it plays in a natural community, defined by how individuals of a species carry out their activities, use resources, and occupy space. Understanding the niche of a single plant or animal species requires in-depth study as well as an understanding of the environment in which the species lives and interacts.

> Conserving biodiversity will help sustain the ecological systems that humans depend on and preserve a wide range of options for the future.

A *community* is an assemblage of species living together in a particular area at a particular time. Communities usually bear the name of their dominant plant species, for example, pine barrens, sedge meadows, and cedar glades. However, the community includes all of the plants living in association with the dominant species plus all of the animals present at a given time. Communities are often perceived as static, but they are actually in a constant state of change—change usually occurs, however, at a rate too slow for humans to note in our brief lifetimes. Communities range in size from less than an acre (e.g., shaded cliff community) to thousands of acres (e.g., mesic hardwood forest). The diversity of a given community is determined by the variety and type of species present, the intricacies of their interactions, and the age and stability of the community. The community diversity of a landscape is influenced by the number of communities present, the degree of difference among the communities, and how the communities are distributed.

An *ecosystem* is a dynamic complex of plants, animals, and microorganisms and their associated non-living environmental components interacting as an ecological unit. An ecosystem takes the biotic community one step further to encompass interactions with the abiotic environment, which includes moisture, temperature, oxygen, sunlight, soil, and all the other non-living physical and chemical conditions. The *biotic* (living) and *abiotic* (nonliving) *environment* interact continuously. Often, this interaction takes the form of complex processes that move gases, chemicals, and minerals in endless cycles such as the carbon cycle, water cycle, and nutrient cycle. For example, a downed tree will, through leaching and decomposition, recycle its nutrients back to the ecosystem to be used by other living organisms. The canopy gap created when the tree was downed will let in sunlight, altering conditions on the forest floor and providing opportunities for new plant species to become established. While all this is happening, the tree is providing shelter for mice and salamanders, food for invertebrates, and substrate for plants. This tiny ecosystem exists within a much larger forest ecosystem that might encompass thousands of square miles. In this larger system are hundreds of species of plants, hundreds of animal species, and probably thousands of species of microorganisms. Ecosystems are constantly changing in response to short-term human impacts such as timber harvest and naturally caused perturbations such as fire or disease, along with long-term influences such as climatic change.

The interactions that connect microorganisms, plants, and animals with the nonliving environment are all part of biological, physical, and chemical cycles that have been occurring on Earth for millions of years.

Within ecosystems, the processes of ecological *succession*—that is, the progressive changes in species composition, organic structure, and energy flows over time—are also constantly at work. Large ecosystems contain a mosaic of successional stages—a forest may have large areas of fully mature trees, but will also have open areas with shrubs, patches of young trees growing up after a blowdown, and other vegetative communities within the larger matrix of the mature forest. Ecosystems are in turn part of the larger *landscape* of adjacent and interacting ecosystems. Surrounding lands can significantly affect the character of an ecosystem; therefore, ecosystems must be considered within the context of the broader landscape.

Wisconsin is located where three of North America's great natural borders join. Here, East meets North and West to create a wealth of biological diversity. It is DNR's challenge to work with Wisconsin citizens to conserve this natural heritage.

Wisconsin is blessed with great biodiversity. Located at the junction of three of North America's *six biotic provinces*—the eastern deciduous forest, the northern boreal forest, and the temperate grasslands—we have a wealth of species and natural communities. Curtis (1959) delineated 21 major plant communities for Wisconsin, plus 13 lesser communities restricted to small areas. Approximately 1,800 native vascular plant species are known in Wisconsin, along with 657 species of vertebrates. In addition, there are thousands of species of nonvascular plants and invertebrates. DNR's challenge is to work with Wisconsin citizens to conserve this biological wealth.

Historical and Current Perspectives in Resource Management

Throughout the history of natural resources management, decisions have been based in part on the personal values of individuals. Today, each DNR employee has a personal history and set of values related to natural resource management. Consider, for example, a group of managers standing on a hillside looking out over an expanse of land below. One person notes the low mounds and plains that indicate glacial topography. Another's eyes go straight to the creek meandering through the scene; this person wonders what fish are present and if they get to any size. Another person in the group spots a small plot of millet growing on the otherwise fallow land and comments that it's probably a wildlife food patch. Yet another scans the land with binoculars, looking for wild flowers and signs of any unusual habitat. Some think of this piece of land as potentially something to manage for a natural "product" such as grouse; others in the group think of it primarily as something to preserve or to restore to its original natural condition. If they examined their personal feelings about the land, some would discover that they view themselves as part of the land. Others would discover that, while they appreciate and respect the land, they view themselves as separate from it, as its manager or steward. All of these individuals are natural resource professionals, and while they have many things in common, they also have obvious differences. Most of these differences are due to training, experiences, and *values*. A variety of values about the environment have prevailed during different periods of history.

Development of Conservation Ethics: 1850s to 1950s

Current environmental values and viewpoints are rooted in two different schools of thought that developed in the latter half of the 19th century. These are often referred to as the preservation ethic and the conservation ethic.

The **preservation ethic**, first articulated by Ralph Waldo Emerson and Henry David Thoreau in the mid-1800s, and later espoused by John Muir and others, focused on the spiritual value of nature and viewed its preservation as a moral obligation. The

Each DNR employee has a personal relationship to natural resource management. As a group of managers stand on a hillside and look over an expanse of land below, each will see the same scene through the filters of their personal experiences, traditions, and values. If we come to understand the historical roots of our traditions and values in resource management, we may better understand the perspectives of others and work with diverse views to find solutions.

preservation ethic was a reaction to the large-scale urban, industrial, and agricultural development that seemed to Emerson, Thoreau, and Muir to be crowding out natural environments. This ethic viewed nature as having intrinsic value apart from its utilitarian value. Thoreau's statement that "in wildness lies the preservation of the world" sums up the preservation viewpoint. Although the movement created a tremendous awareness of natural beauty and succeeded in preserving some of our nation's most scenic landscapes, it did little to stem the exploitation of species. However, this spiritual valuing of nature remained a strong theme throughout the 20th century and became entwined with the resource conservation ethic in many ways. It is the philosophical foundation for the way that many managers and citizens relate to the environment today. In Wisconsin, the preservation ethic sparked the establishment of Wisconsin's first state park in 1900 and the identification of other areas of natural beauty to be purchased in succeeding years. In 1907 the State Park Board was established to oversee this task. And the nation's first Natural Areas program began in Wisconsin in 1951.

We do not need to choose between preservation and conservation. Rather, they each have a role to play as we create an overall set of principles for managing resources.

The prevailing source of values in natural resource management for the past 100 years or so has been the resource **conservation ethic**. This ethic grew out of the crisis created by the overexploitation of nature that occurred during Euro-American settlement. As fish and wildlife populations were decimated and the forests reduced to stumps, the public demanded government intervention. As a result, the first conservation agencies were formed. Although these first managers had little formal training in science or natural resources, the subject matter of their work gradually made its way into colleges and universities as the need for trained managers increased and as the complexity of the work became evident.

In Wisconsin, the conservation ethic was expressed in the establishment of departments, boards, and commissions to protect and manage the state's resources. In 1903, a State Forestry Department was established, followed by the first forest ranger school and game warden school in 1911-1912. The Wisconsin Conservation Commission and Conservation Department were created in 1915, pulling together boards and commissions covering parks, fish, game, forests, and law enforcement.

These first managers focused their work on fish, wildlife, trees, and other resources that had potential for regeneration. Their job was to manage these highly utilized resources for the "greatest good," to benefit the greatest number of people over the long term. Conservationists did not advocate preservation for its own sake. They believed that careful management could produce a sustained flow of benefits with an emphasis on valuable species such as deer or pine trees. The motto of the conservation ethic became "wise use" or "use without abuse." Finely honed professions developed, each specializing in a particular resource. As the professions became more scientific, they also became more quantitative. This increased technical orientation plus the passage of time may have obscured the basic value lying at the core of these professions, but the resource conservation ethic was continuing to exert a profound influence.

Aldo Leopold's **land ethic** transcended both the resource conservation ethic and the preservation ethic. The land ethic, which Leopold articulated just before his death in 1948, focused on the interconnectedness of nature and the rightness or wrongness of human interaction with nature. Leopold's simple but compelling statement that "the destruction of land, and the living things upon it, is wrong" sums up the basic premise of the land ethic. The land ethic grew out of Leopold's personal experience as a forester and game manager practicing traditional techniques of range management, predator control, and user regulations. The land ethic does not oppose human use of nature or scientific management of natural systems; in fact, it assumes both. What matters is how we go about our use and management of nature. According to the land ethic, it is in the self-interest of humans to treat the land well since we are part of nature and our well-being depends upon it. Leopold's work led to an awareness that management actions have far-reaching and often unpredicted consequences and that the natural world is far more complex and interrelated than scientists had previously realized. This thinking was gradually integrated into the developing science of ecology and called for a new consciousness regarding our relationship to the land.

The Turning Point: *Silent Spring*

The decades since the emergence of Leopold's land ethic have seen a variety of landmark events concerning the environment and natural resources. Foremost among these was the publication in 1962 of Rachel Carson's book *Silent Spring*. This book raised the specter of a soundless spring—a spring without insects, invertebrates, frogs, birds, and other animals—and brought home the meaning of the effects of pesticides in complex food webs. Its publication marked an end to a period of innocence for the American public. The notion that we could load the earth with chemicals and wastes with no consequences gave way to a more sober, realistic view of limits and harm. As more evidence of damage surfaced, public pressure to regulate pollution increased. This new public concern focused on the environment as a whole rather than the species orientation that had dominated decades earlier. In 1967 Wisconsin became the first state to ban the pesticide DDT. At the national level, comprehensive environmental legislation (Environmental Policy Act, Clean Water Act, Clean Air Act) was put in place. This legislation added a new dimension to natural resource management and led to the creation of new environmental protection professions.

"The land ethic simply enlarges the boundaries of the community to include the soils, waters, plants, animals, or collectively: the land." (Aldo Leopold, The Sand County Almanac)

The Growth of Environmentalism: The 1960s and 1970s

For natural resource professionals, the environmental movement of the 1960s added new values to the preservation ethic, resource conservation ethic, and land ethic. This new set of values has been termed the **environmental protection ethic**. This ethic views the environment as a set of physical systems that must be maintained in a healthy, functional state. Regulating pollutants going into systems, monitoring movement of pollutants within systems, and predicting their impact are prime concerns for natural resource managers working in environmental protection. Concern for species was not left out of this period; in fact, the reasons for the decline of species was now seen in the larger context of environmental damage. The Endangered Species Act of 1973 provided a legal means to conserve the ecosystems which support endangered species and threatened species. This act also gave expression to Leopold's adage that "the first rule of intelligent tinkering is to save all the parts."

Multiple values, often appearing as incompatible, were simultaneously developing among citizens. For example, one value held that we must protect the environment for future generations. Another held that we must protect the environment primarily for present economic benefits. Individuals with this latter viewpoint often saw human qualities as separate and "at the top of" nature, giving people special rights and responsibilities. An opposing viewpoint saw nature as having value in its own right and violation of nature as immoral; humans were seen as just one part of nature, perhaps a small and inconsequential part in the total scheme of things. The result was lively and intense public debate, but no clear or unified vision developed to guide policy decisions. The first Earth Day, led by

The notion that we could load the earth with chemicals and wastes with no consequences gave way to a more sober, realistic view of limits and harm and paved the way for the environmental protection ethic.

In 1967 the Executive Branch Reorganization Act brought together closely related traditional conservation tasks and newly emerging environmental protection responsibilities to create the Wisconsin Department of Natural Resources.

Wisconsin U.S. Senator Gaylord Nelson, was held in 1970. This event drew many people into the debate and widened the base of support for environmental protection.

During this period, single-species management was still the rule in resource management, but the strong Aldo Leopold tradition in Wisconsin was also being felt. For example, wildlife and fisheries managers who were aware of the value of wetlands for a wide spectrum of species (not just target species like ducks or northern pike that the public normally associated with wetlands) broadened projects to benefit the system as a whole. Acquisition of land adjoining trout streams in the Central Sands counties not only protected the stream habitat and allowed fishing access but also protected the bottomland vegetation adjacent to the stream. Land acquisition for watershed protection also began in this era.

Although Wisconsin had regulated pollution as early as 1927, when the State Committee on Water Pollution was created, the 1960s marked the beginning of a tremendous increase in programs devoted to the environment. Much of this was due to the formation of the Wisconsin Department of Natural Resources, which occurred in 1967 when the Executive Branch Reorganization Act, developed under the guidance of the Kellett Commission, became law. This law brought together closely related traditional conservation tasks and newly emerging environmental protection responsibilities. It merged the Department of Resource Development, air pollution functions of the State Health Board, and the Wisconsin Conservation Department to form a single state agency.

The merging of these programs also meant a merging of administrators and managers with different historical influences, values, and approaches to problem-solving. The new DNR organization reflected these differences. For example, the Division of Resource Management was organized into separate bureaus for management of fisheries, wildlife, endangered resources, forestry, and parks, with research and property management functions providing support. The Division for Environmental Quality was organized around the major abiotic components of the environment (air, water, land), emphasizing their management and regulation, mostly through permit control.

Emergence of Concern for Biological Diversity: 1980s-Present

The next major step in the evolution of natural resource management occurred in the 1980s, when public concern for loss of natural spaces and rapidly increasing scientific knowledge about the interconnectedness of all the pieces of ecosystems merged to produce both public and scientific interest in managing resources with the goal of conserving biological diversity. This increased concern for biological diversity cannot be attributed to any given person or group. Indeed, the thoughts of many people from around the world—scientists, managers, philosophers, and the public—contributed to its development. Scientists have come to understand that some concepts—especially the idea that ecosystems reach a "steady state" or "climax" condition—do not provide an accurate picture. This correction to an established assumption has led to questioning some established management principles and activities. These changing concepts of management place new and challenging demands on DNR employees and the agency as a whole.

The conservation of biological diversity became the next major step in the evolution of natural resource management.

Throughout 1993 and 1994, discussions with DNR staff, county forest administrators, leaders of groups representing business, environmentalists, hunting and fishing organizations, academics, and members of the public have shown us that

Wisconsin residents do indeed hold a wide range of opinions about biodiversity. Most people we spoke with do agree on a definition of biodiversity similar to the one used in this report. Most feel that biodiversity is a serious issue, brought to public attention by a combination of both advances in scientific knowledge and public concern for loss of wild and natural places. Some believe that changes in management must be made, but that we have time to think through changes and make incremental changes. Others feel that resource managers have not adequately considered biodiversity in their decisions, and that there is an urgent need to revise management practices and to set aside large biodiversity reserves to protect ecosystems. Still others are concerned that biodiversity is too complex a concept on which to base management actions. They may want to manage to conserve biodiversity but are unsure what actually needs to happen "on the ground." Some people we've spoken with feel that concern for biodiversity is just a fad, others think of it as the newest environmental buzzword, and some said that resource management professionals have been managing for biodiversity all along.

Those with whom we spoke do agree that ignoring issues until inflexible positions have been staked out is not the way to handle biodiversity issues in Wisconsin. Factual data analysis together with open-minded dialogue among citizens of diverse perspectives will be required to develop a consensus for policies that integrate ecology, economics, and human values. Biodiversity and economic health must not be seen as conflicting; they must be integrated into rational resource policies that will enhance the lives of present and future generations. The practice of ecosystem management, as described later in this chapter, will play an important role in bringing this integration about.

DNR's Role in Conserving Biodiversity

By creating the Department of Natural Resources, the Wisconsin Legislature recognized the need for an integrated approach to protecting, conserving, and enhancing Wisconsin's environment and natural resources. The legislature further recognized that the needs of traditional conservation programs and environmental programs were closely interrelated and that forming a single agency would provide better management and greater public benefit. Thus, the Department's mission statement reflects this holistic approach:

- Protect and enhance our Natural Resources—our air, land and water; our wildlife, fish and forests.
- Provide a clean environment and a full range of outdoor opportunities.
- Insure the right of all Wisconsin citizens to use and enjoy these resources in their work and leisure.
- And in cooperation with all our citizens to consider the future and those who will follow us.

Managing to conserve biological diversity helps the Department carry out this mission. Although biodiversity was not a common term until recently, the Conservation Act of the early 1920s provides the direction required for our present-day response to biodiversity as a management issue. Chapter 23.09 of the Wisconsin Statutes states that "the purpose of this (conservation) section is to provide an adequate and flexible system for the protection, development, and use of forests, fish and game, lakes, streams, plant life, flowers, and other outdoor resources in this state." The balance of protection, development, and use of our natural resources demands that we conserve the long-term functional health of ecosystems, including their biological diversity.

Wisconsin citizens hold a wide range of opinions about the conservation of biodiversity. Most people who shared their thinking with us agreed on a basic definition of biodiversity similar to the one in this report. This common ground will be important as we seek to integrate ecology, economics, and human values in resource management policy and practice.

Ecological Issues

Plants, animals, and humans colonized Wisconsin as the glaciers receded 10,000-12,000 years ago. The earliest archeological evidence of human presence in Wisconsin dates from 11,000 years ago. Thus, the biotic communities that took hold in Wisconsin after the glaciers receded were influenced by human activity from the beginning. The size of the human population in Wisconsin in the millennia before European contact is a subject of speculation. At one time the settlement of Cahokia, in southern Illinois, supported a population of perhaps 30,000 individuals. We can assume that pre-Columbian Wisconsin also had a large human population, although there is no evidence that communities the size of Cahokia were located here.

The native populations managed the landscape to produce food, fiber, fuel, and other needs. We do not know how much land might have been in agriculture, but there is archeological evidence of irrigation, raised beds, and other intensive farming practices. Farming and the use of fire for agricultural clearing and for managing animal and plant populations were possibly the most significant factors affecting natural succession of plant communities in Wisconsin. In northern Wisconsin, native populations hunted and fished intensively, and impacted the northern forests through gathering firewood, creating clearings for settlements, favoring plants useful for medicine and food through cultivation and management, and using forest materials for tools and shelter.

When Europeans landed in the New World, this picture changed dramatically. Native populations lacked immunity from such diseases as smallpox, influenza, measles, venereal diseases, and the common cold. Beginning in 1492, disease spread along trade routes even to tribes that had no direct contact with Europeans. Throughout North, Central, and South America, native populations declined dramatically due to disease epidemics. When Europeans arrived in Wisconsin in the 17th century, they found a much smaller human population than had existed two hundred years before. The result was that much of the area may have become more "natural" due to less human management and use.

The first Euro-American settlers, arriving in Wisconsin in the 1830s and 1840s, found a landscape characterized by extensive forests, grasslands, wetlands, and a variety of other biotic communities. While the species of plants and animals the Europeans found here had adapted to Wisconsin's soils and climate over thousands of years, they had done so in the presence of humans who were continually affecting the landscape to the extent allowed by their population size and their technology. Europeans brought technologies of the industrial age that began more intensive manipulation of the environment. They also introduced, both purposefully and accidentally, many non-native plants and animals to compete with the native species, often resulting in broad changes in ecosystem composition, structure, and function.

Today, Wisconsin's landscape reflects a high degree of human use. It is a mosaic of urban areas (cities, towns, suburbs), production areas (farms, mines, industries, commercial forests), multiple-use areas (parks, lakes, public forests), and protected natural areas (conservancy, wilderness). This patchwork bears little resemblance to the landscape the native populations knew, or to the one the first European explorers saw.

Managing Wisconsin's natural resources to conserve biodiversity requires that we understand how today's patterns of land and resource use were created from these earlier landscapes and how human activities and natural processes continue to produce those patterns (Fig. 2). The activities and processes of particular concern in relation to biodiversity can be grouped into three major categories: ecological *simplification, fragmentation,* and *environmental pollution*. While *simplification* and *fragmentation* result from both natural

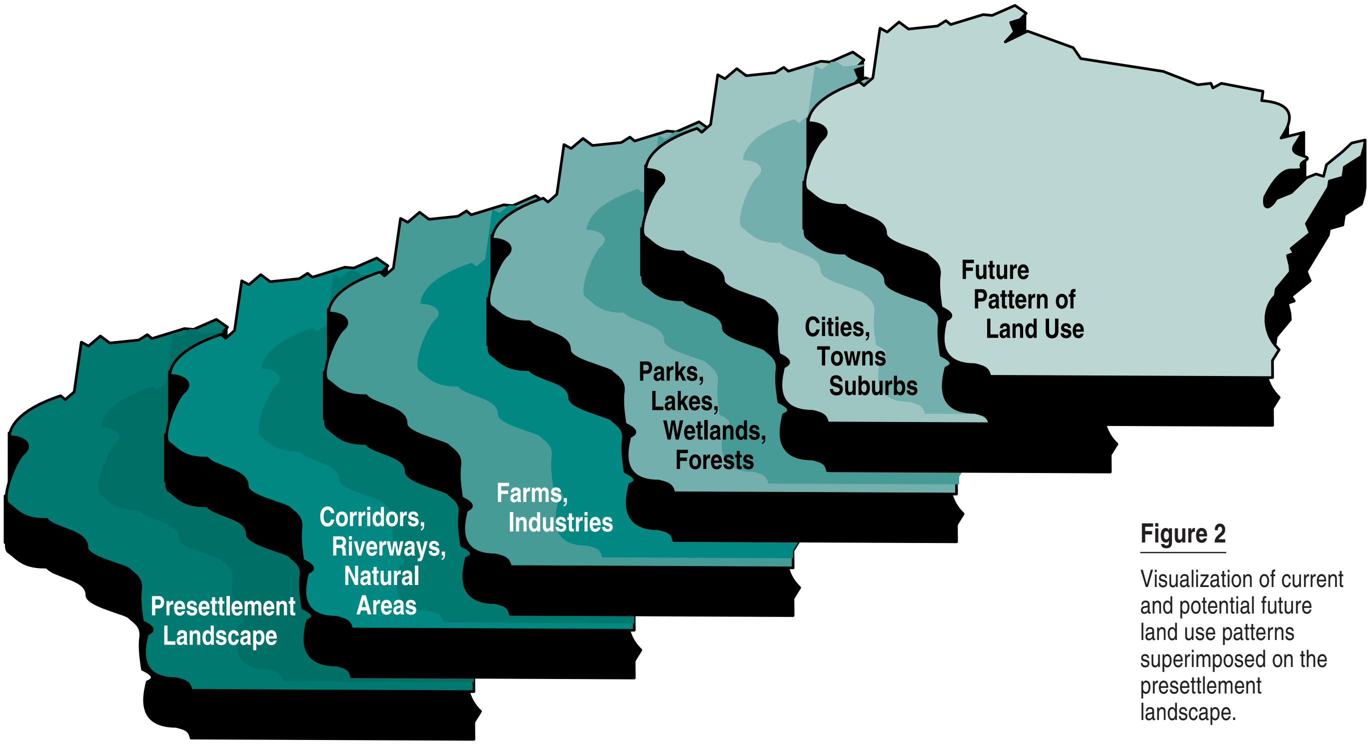


Figure 2

Visualization of current and potential future land use patterns superimposed on the presettlement landscape.

and human-caused events, human actions tend to alter the ecosystem at an increased rate and at a greater magnitude than natural events do. Certain species, communities, and ecosystems are not doing well in Wisconsin because of these human-caused changes. In contrast, populations of generalist species that are well adapted to the simplified or fragmented environment are flourishing. *Environmental pollution*, which is almost entirely a result of human activity, also poses formidable threats to biodiversity. Although the effects of pollution on ecosystems are often similar to those caused by simplification and fragmentation, the causes and mechanisms of pollution are very different. Understanding simplification, fragmentation, and environmental pollution will help us understand the ecological trade-offs and consequences of our decisions and will help define the institutional, social, and economic choices that will be made in the future to guide DNR's activities in relation to biodiversity.

Our goal is sustainable ecosystems in the context of today's landscape. Knowledge of the presettlement vegetation will help us recognize the ecological potential of an area and answer questions about how, how much, and where biodiversity can be restored.

Although this report focuses on natural vegetation and natural communities, we also need to consider urban and agrarian systems as we continue to move forward to ecosystem management, because humans are an integral part of the environment. Our goal is sustainable ecosystems—whether highly modified by humans or largely natural—that maintain ecological *composition, structure*, and *function* and maintain genetic, species, community, and ecosystem diversity across all land uses.

For natural communities, early 19th century vegetation can be used as a guide for restoration that provides valuable insights into the ecological potential of an area. Although recreating this former state would be an unrealistic goal given current conditions (except in some natural reserves), it is important to understand what was here in the era prior to Euro-American settlement. This period represents a time when scientific biological observation began, when native plant communities were less disturbed by management activities and fairly undisturbed by the many species of non-native plants and animals. This information can guide us as to what elements of biodiversity can be protected and restored, in what levels of abundance, and in what geographic areas, helping us reach our goal of sustainable ecosystems in the context of today's landscape.

What follows is an overview of ecological simplification, fragmentation, and environmental pollution, with an emphasis on explaining what these concepts mean and how they impact biodiversity. The concept of scale provides a foundation for understanding how to deal with these issues (see inset).

Scale

Scale is the relative amount or degree of something, often expressed in terms of a progressive classification as to size, complexity, or importance. In management of natural resources, scale is often used to describe the scope of a management action—whether site-specific, local, regional, or statewide in space, and annual, seasonal, or successional in time—and the degree to which the management action alters the existing plant and animal communities.

Thus, when the concept of scale is applied to ecosystems, it has both spatial and temporal meanings. *Spatial scale* is used to describe the geographic size of a community or ecosystem (Fig. 3). This size can range from a microsite such as the underside of a leaf on the forest floor, to the entire forest, to the larger landscape. The biosphere, including earth, its enveloping air mass, and all its biota can be thought of as the largest scale from a biological point of view. *Temporal scale* describes the time required to complete a life history event or an ecological process, such as the a series of successional stages (Fig. 4). For life history events such as life cycles, temporal scale can vary from a few hours for certain microbes and insects to thousands of years for ecosystems. Ecological processes can vary from a few seconds for individual biochemical reactions to decades for forest regeneration. When tied to geologic changes, temporal scale reaches millions of years.

For ecological purposes, the amount of detail with which an ecosystem can be described for management planning is determined by the spatial and temporal scales. Due to time and resource constraints, we are often able to provide more detail at smaller scales than at larger scales. We often speak of this situation using the term resolution, i.e., as having a high degree of resolution at small scales and a low degree of resolution at large scales. For example, in an endangered plant inventory of a very small plot, we may be able to thoroughly sample the plot inch-by-inch. An inventory of a large area would be done at a lower degree of resolution, perhaps by running transects at intervals across the area. The former sampling approach gives us a lot of information about a very small area, and the latter gives us less detail but includes a wider geographic area and a larger amount of total information on plant distribution.

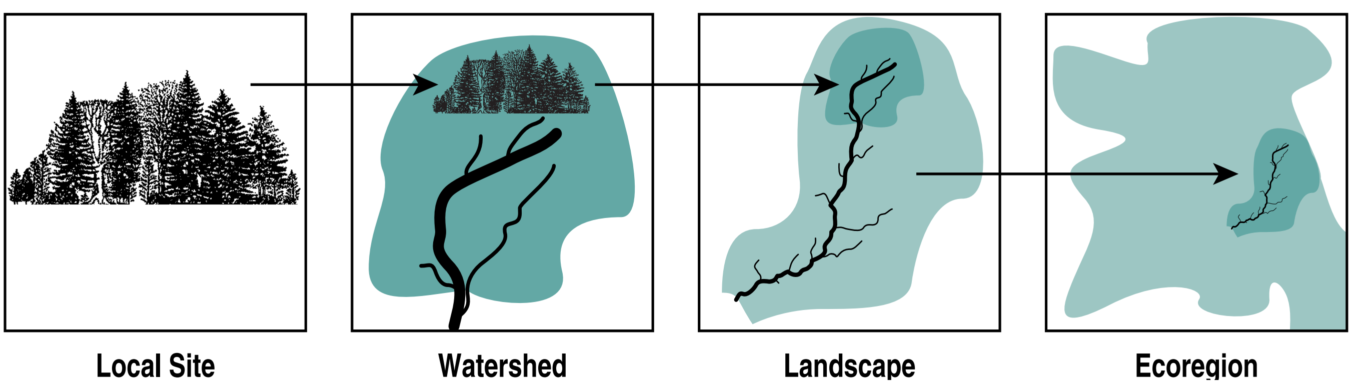
The desired spatial scale for overall *ecosystem management* planning is the *landscape*. A landscape is an area composed of interacting ecosystems that are related due to underlying geology, landforms, soils, climate, biota, and human influences. Broad management goals will be set at this scale and will relate to relatively large geographic areas, using the information collected with a low degree of resolution, or less detail, as described above. Management of specific sites within the broad landscape will occur based on goals set at the landscape scale. Information with a high degree of resolution will be collected at specific sites as needed to check the accuracy of goals set on the landscape scale or to fine-tune management plans for specific sites.

Landscape-scale management encourages us to approach problems and projects using the broadest scale with ecological meaning. Thus, the geographic area or *region* included in any particular analysis will be determined by our knowledge of the breadth of the interconnections among the biotic communities involved. For example, a proposal to create a new Natural Area in Wisconsin for the protection of biodiversity would include a series of considerations—among these are the size and quality of adjacent buffer areas needed to protect ecological integrity on the site; the relative importance of the site to biodiversity within a statewide view of community and ecosystem status; and concerns such as the transport of pollutants or the condition of migratory bird habitats on continental or inter-continental scales. Or, a proposal to acquire land to support an anadromous sport fishery on the Great Lakes would include an analysis of the ecological conditions of all the streams and watersheds on the Wisconsin shoreline of Lake Michigan and/or Superior. The analysis would indicate how the overall management plans for these streams address statewide issues of biodiversity as well as other important related issues such as recreation and water quality.

Biodiversity is maintained by the presence of an array of communities and species occurring within ecosystems which are intact and sustainable, that is, they usually contain a wide range of species and natural processes. The appropriate scale for management must be considered and deliberated along with other considerations if biodiversity is to be preserved or enhanced. If we are not aware of the concept of scale in planning a proposed action or do not understand the implications of our choice, we run the risk of developing inappropriate plans and prescriptions. Worse, we can unknowingly change the community or ecosystem involved. These choices are complex, for decisions that favor increasing diversity at a given scale may decrease diversity at other scales.

Figure 3

Examples of spatial scales can be observed with the "nesting" of small areas, such as a local site, within progressively larger geographic units.



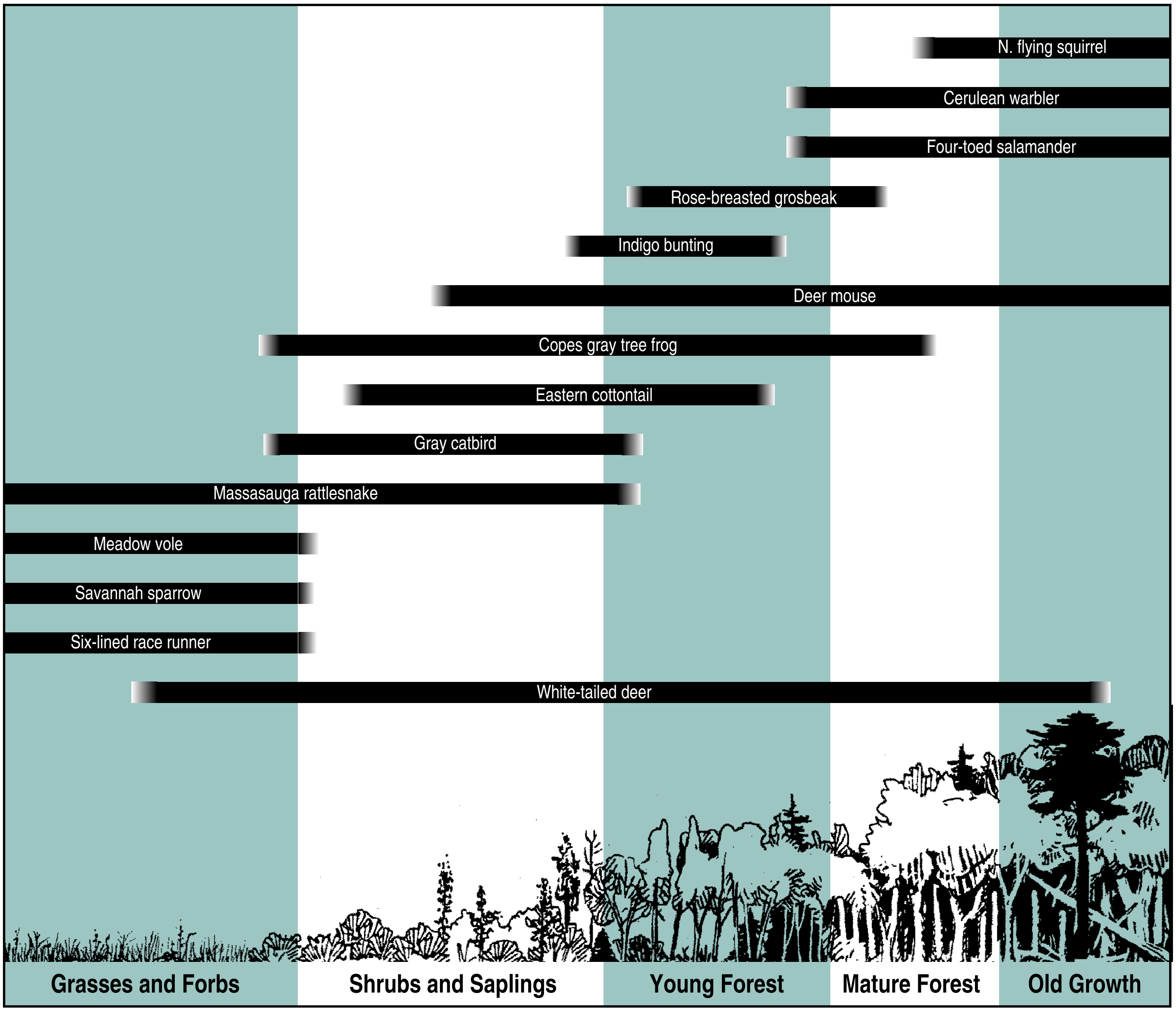


Figure 4

Examples of temporal scale can be observed with the succession of a southern Wisconsin grassland to a forest. The composition of plant and animal communities change along with the landscape. Adapted with permission from material produced by the Minnesota Department of Natural Resources.

Ecological Simplification

Ecological simplification means that the interrelationships between organisms and their environments are reduced in number and complexity. Simplification can be caused by habitat loss, non-native species encroachment, air and water pollution, and many other factors. Although the effects of simplification are complicated and often subtle, they are often discussed in terms of their impact on the three major attributes of ecosystems: *composition, structure*, and *function* (Fig. 5).

Composition

Composition refers to the fundamental elements of natural systems—the specific organisms or groups of organisms that a unit area or geographic area contains. At the statewide level it includes ecosystems, communities, species, and their genetic composition. Thus, an ecological system simplified in terms of composition might have reduced numbers of species present or a limited gene pool for a remnant or isolated species.

The most radical impacts on composition occur when there is total destruction of the biotic, abiotic, spatial, or temporal needs of species. The conversion of native prairies, savannas, wetlands, and southern forests to agriculture and urban development since Euro-American settlement are among the most conspicuous examples.

The introduction of exotic species provides another example. Purple loosestrife, known to exist in restricted areas of Wisconsin's wilds for over 40 years, has spread across three-quarters of the state in ten years, seriously simplifying many wetlands. Garlic mustard has invaded southern Wisconsin forests, displacing native forbs and dependent fauna. Common buckthorn and Japanese honeysuckle have invaded southern mesic and dry mesic forests, while glossy buckthorn has invaded wet forests and bogs. All three have displaced forbs and shrubs, and in bogs even established trees are being lost to competition. In some southern Wisconsin oak forests, buckthorn and honeysuckle encroachment has begun to significantly reduce oak regeneration. Similarly, the rusty crayfish, introduced as sport-fishing bait, has spread to a large number of inland lakes, displacing native crayfish and disrupting entire plant communities. The result has been an adverse impact on other fauna such as fish, invertebrates, and zooplankton that are dependent upon the aquatic macrophytes consumed by the rusty crayfish.

When ecosystems are simplified, we may observe a reduction in species numbers, their gene pools, the physical structure of their habitats, or the complexity of life-sustaining processes such as food webs or water cycles.

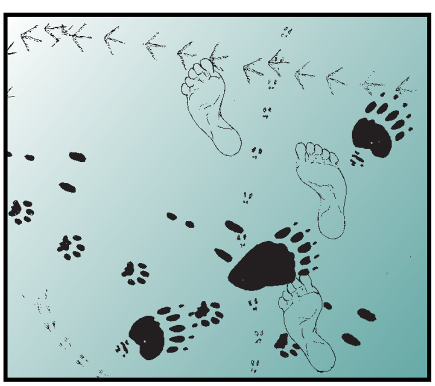
Thus, the presence of non-native species within terrestrial and aquatic communities and ecosystems often leads to displacement of native species and change in ecosystem function. Displacement is usually not one for one; one exotic species can displace many native species. Because exotics are generally introduced without consideration for natural biological and ecological controls, once they "escape into the wild" they sometimes prove very successful in competing against native species. Today, an estimated 22% of Wisconsin's 2,300 vascular plant species are non-native species.

Structure

Structure refers to the pattern or physical organization of an area; it is used to define physical appearance both vertically and horizontally. Vertical stratification is readily visible in a mesic hardwood forest, where one group of species occupies the canopy layer, another group the subcanopy, another the sapling layer, and so forth, down through shrubs, tall herbs, short herbs, and ground cover (surface) plants. Horizontal variation occurs across the length and breadth of any community or, at a larger scale, across sub-regional and regional landscapes. Canopy gaps, forest

Figure 5

The three major attributes of ecosystems: composition, structure, and function. Ecological simplification occurs in relation to all three.

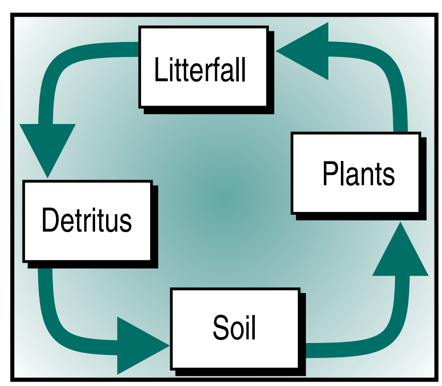


Composition

The make-up of an ecological unit, including the specific organisms or groups of organisms in a particular area.

Structure

The pattern or physical organization of an area. It has both vertical and horizontal components.



Function

The roles that the living and nonliving components of ecosystems fulfill in driving the processes that sustain ecosystems.

A simplified ecosystem has little of the structural complexity that creates diverse habitat opportunities as a basis for ecosystem function.

openings, seasonal ponds, savanna alternating with prairie, riffles alternating with slow water, and backwaters adjoining main streams are all examples of horizontal variation. The location of vegetation in a horizontal plane is related to the slope, exposure, soil, proximity to other plants of the same or different species, and dispersal mechanisms. Vegetative debris—fallen trees and limbs, standing dead trees, and leaf and forb litter—is also part of a community's horizontal and vertical structure.

Animals follow a pattern of vertical and horizontal organization similar to plants. For example, birds and invertebrates that occupy the canopy of a forest community differ from those that occupy the midlevel, many of which differ from those residing on the forest floor. Similarly, the fauna associated with a lake's emergent vegetation differ from the animals associated with the floating or submerged vegetation.

A simplified ecosystem has little of the structural complexity that creates diverse habitat opportunities as a basis for ecosystem function. For example, a forested area being managed on short rotation for even-age, single-species trees is a structurally simplified system. Because the tree species are all of similar age and are cut before other layers of vegetation can become well established, there is little vertical or horizontal layering. Animal species inhabiting the area would likewise reflect lower diversity than would be found in a forest with trees of various ages.

Function

Function refers to the roles biotic and abiotic components of ecosystems (e.g., producers, consumers, digestors, transformers, water, minerals, and microclimates) fulfill in driving the *ecological processes* (e.g., water and carbon cycles, mineral and nutrient cycles) that sustain the ecosystem. Every naturally occurring organism within an ecosystem has one or more roles in sustaining the dynamics of that ecosystem. For example, on an ecosystem or landscape scale, vegetation controls the community environment, is the primary source of energy for other organisms within the community, and is the principal source of minerals and chemical compounds necessary to sustain animal life. Animals are the main consumers, with primary consumers eating plants and secondary consumers eating other animals. Still other plants and animals along with fungi and bacteria perform essential functions as decomposers and transformers of waste products and detritus, converting dead material back into elements essential to plant growth. Each individual plant and animal has a functional role in the support of other species and the community as a whole.

Increased diversity and functional complexity generally provide resilience to ecosystems. Conversely, for a given ecosystem, reduced biological diversity may result in less resilience. In less biologically diverse systems minor changes in energy flow or population structure produce major changes in energy transfer and populations. Unpredictable and chaotic changes may occur. A community will cease to be part of a viable ecosystem if there is significant functional loss. The Lake Winnebago system provides a good example. An increase in water level in the system and other factors led to a severe reduction in aquatic plant populations beginning in the late 1800s. Wind and wave action across these large expanses of water prevented macrophyte reestablishment by increasing turbidity, eroding the shoreline, and uprooting plants. Populations of invertebrates, fish, and waterfowl have fluctuated through the years with a general trend toward decreasing numbers. Numerous attempts to manage the water level have met with limited success due to the great functional losses to the system. A system-wide approach is now being taken through DNR's Lake Winnebago Comprehensive Management Plan and offers a much better chance for improvement.

Fragmentation

The natural variation of biological communities across a landscape, often referred to as "natural patchiness," has always been a normal part of the environment. At the time of Euro-American settlement, the natural landscape of Wisconsin was broken up into wetlands, prairies, forests, lakes, and streams, all occurring in numerous patches of varying sizes. Some species, such as prairie chickens, thrived only on very large patches of suitable habitat. Others were more successful at the interface edge between plant communities and took advantage of two or more habitat types—for example, the white-tailed deer which uses forest, brushland, and prairie edges.

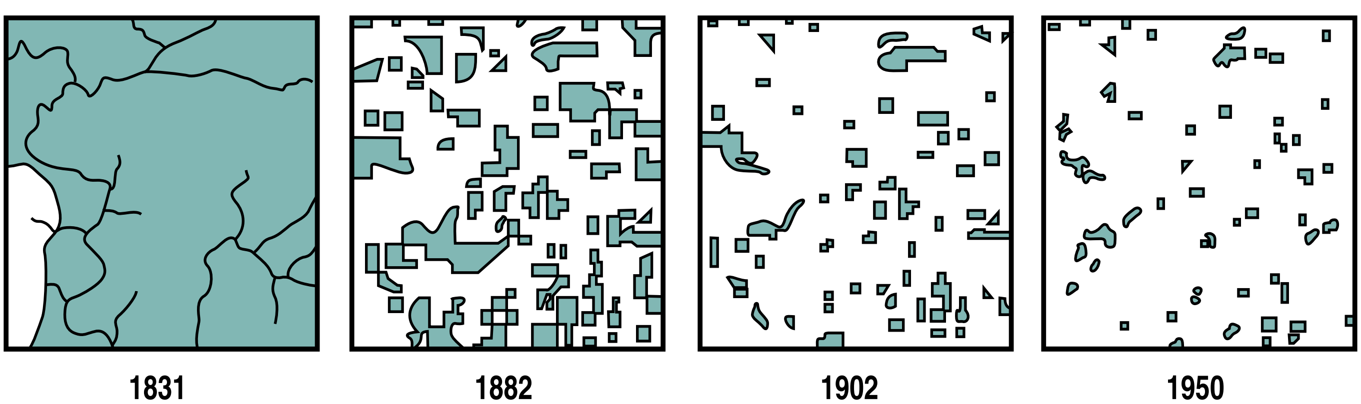
Many animal species need a high degree of "patchiness" because their life requirements are met by using different habitats at different times. Others, such as grassland birds and interior forest songbird species, are favored by relatively large, continuous habitats of similar vegetation. More subtle differences in soil, microclimate, moisture level, slope, and aspect permit plants to thrive in one area and not another. For example, the northern forest ecosystem includes numerous communities representing a range of successional stages as well as natural patches of oak, aspen, balsam fir, and tag alder, which under natural conditions gradually blend one into another. This "patchiness" may often protect plants from catastrophes such as disease, insect outbreaks, and fire.

> In order to observe fragmentation of biological communities or ecosystems, we look at the pattern of fragments on the landscape, their sizes and proximity to one another, and the types of edge that define them.

Natural landscapes gradually merge one habitat type with another or leave corridors or ways for animals to move and still stay in their preferred habitat. Fragmentation is the breaking up of large and continuous ecosystems, communities, and habitats into smaller areas surrounded by altered or disturbed land or aquatic substrate. Fragmentation eliminates corridors and causes the abrupt meeting of different habitat types. In Wisconsin human activity has greatly fragmented the landscape, producing changes that are different from natural landscape heterogeneity or patchiness. For example, during Euro-American settlement the northern forests were logged and many areas were burned, leaving only scattered "islands" of forest remaining. These disturbances in the north occurred within a 50 year time period. After that time, the land-use pattern remained "undeveloped" in character and the land progressively grew back to forest. As agriculture and urbanization grew in southern Wisconsin, the southern forests, prairies, and wetlands were broken into increasingly smaller and more isolated fragments that remain today. Roads, sewer, and utility corridors; dams; residential, commercial, and industrial development;

Figure 6

Changes in a wooded area of Cadiz Township, Green County, Wisconsin, during the period of Euro-American settlement. The shaded areas represent land remaining in, or reverting to, forest. This fragmented landscape is likely to exhibit effects from changes in the amount of edge, reduced size of fragments, and isolation of fragments. From Curtis (1956) with permission of the University of Chicago Press.



and land clearing and conversion continue to contribute to fragmentation in both the north and the south. Some traditional resource management practices have also contributed to fragmentation.

Many species continue to do well in these artificially segmented landscapes. Some, such as white-tailed deer, are even more successful than they were historically. However, many species of plants and animals lose ground as a result of increased fragmentation. Fragmentation generally results in three types of change: fragment size reduction, increased isolation of fragments, and increased edge-to-interior ratios (Fig. 6).

Size Effects

As the size of a particular fragment becomes smaller and smaller, more and more species disappear from it. For example, very large blocks of prairie historically contained more than 400 vascular plant species and a multitude of animal species including microfauna, insects, herptiles, birds, and mammals. As the prairies were broken up, large ungulates such as bison and large predators such as wolves quickly disappeared. As fragmentation continued, some plant species disappeared and many others became rare. Now many are in serious decline.

The *size effects* of fragmentation are particularly noticeable in the southern and west-central two-thirds of the state. Here major ecosystems (grasslands, savannas, and southern forest) were reduced in size and severely fragmented by agriculture and by urban and rural residential development. Many remnants of these once-expansive ecosystems are represented by community fragments too small to support viable populations of many species. For example, most species of the grassland bird guild are in decline, as are reptiles and amphibians. The ornate box turtle requires a minimum of 250 acres of prime sand barrens habitat to sustain a viable population, but only three or four areas of this habitat size and quality remain.

In the north, communities and ecosystems historically dependent on fire, e.g., the oak and pine barrens, have been fragmented and diminished in size by forest encroachment. Populations of species such as sharp-tailed grouse, which depend on these open areas, continue to decline across their historic range due to loss of barrens and other open habitat.

Isolation

Isolation of habitat patches occurs as the landscape becomes progressively fragmented. Areas of the same type become isolated, not only by distance but by hostile intervening environment, putting plants and animals without adaptations for long-range movement at a severe disadvantage. The inability of a species to move between habitat patches leads to loss of genetic viability and diversity and can ultimately lead to elimination of that species within that fragmented habitat. As the intervening environment becomes increasingly hostile even the more mobile species have their movement between habitat islands thwarted. Today, many community and ecosystem fragments are so far apart and so reduced in size that many animals fail to maintain populations. The communities become closed systems subject to catastrophic change from events such as disease, drought, wind storm, or floods.

Some of the most prominent examples of isolation resulting from habitat or community fragmentation can be found in what is left of the prairie ecosystem. This ecosystem is now severely reduced to small isolated fragments scattered about in a "sea" of agricultural and other lands inhospitable to many of the prairie species, especially invertebrates and plants. Recent survey work in Illinois suggests that at least 15% of what is left of prairie insects are now restricted to prairie remnants. These remnants range in size from two to 1,000 acres; most are in the 2-40 acres in size. As much as 30%-40% of our prairie plants may also be remnant-restricted. Without connecting corridors or "stepping-stones" of close enough proximity and large enough size, many of these species populations will remain permanently isolated and thus subject to inbreeding, continued decline in numbers, and eventual elimination from that patch of habitat.

Aquatic ecosystems are also subject to isolation. All of Wisconsin's large rivers, most of its medium-sized rivers, and many smaller streams have been fragmented by dams. Fragmentation causes streams to become a series of modified ecosystems which no longer represent the native ecosystem in structure, function, and composition. Lake shores have also been fragmented by sand blankets and vegetation removal associated with shoreline developments. Dams prevent fish from reaching upstream spawning grounds, but there are other, more subtle effects of dams. For example, damming frequently isolates mollusks from the fish that host their larval stages; mollusks unable to complete their life cycle because of this isolation are eventually eliminated from the stream. For other species, populations are diminished when individuals succumb to siltation and other effects of damming.

Edge Effects

Edge effects occur near the interface of two or more different habitat types. Edge effects are beneficial for many plant and animal species, since edge allows them to take advantage of two or more habitat types for their survival. However, many other species are negatively affected by too much edge. The concentration of many species near edges causes increased competition, predation, and parasitism. For example, waterfowl nesting near the edges of grassy fields experience high nest predation, as do some songbirds nesting near forest-field edges. Or, some plants may disappear from previously suitable interior habitat when a new edge changes the micro-climate. As community or ecosystem islands get smaller or more disturbed, they become less and less viable for interior plants and animals. In effect they become all edge.

Encroachment of exotic species is closely associated with edge dynamics. In forests, many exotics gain entry to interiors by first getting established in the disturbance zone associated with human-caused disruption. Interior edge, which is more common in the north, is caused by logging, agriculture, blowdowns from wind storms, fire, and residential and commercial development, and takes on the same form and effect as exterior edge. Area- and edge-sensitive interior species are especially vulnerable to interior edge conditions.

Corridors for roads, power transmission lines, and pipelines create linear edge throughout the north, while in the south, these corridors sometimes bisect woodlots, wetlands, and grasslands. These corridors are havens for edge species and allow for penetration of species into otherwise continuous communities and ecosystems.

Environmental Pollution

Environmental pollution is the human-induced addition of many types of substances to air, land, and water in quantities and/or at rates that harm organisms, habitats, communities, ecosystems, or human health. Examples are nutrients, heavy metals, organic compounds, and sediments. Pollution may change the physical, chemical, or biological characteristics of air, water, or land, thus affecting the health, survival, or activities of living organisms in a variety of detrimental ways, including impacts on genetic, species, community, and ecosystem diversity.

Any Department policies relating to biological diversity need to consider the effects of pollution and the efforts required to manage resources that have been adversely affected by pollution. The following examples illustrate some of these effects as they relate to water, air, and land resources.

Pollution may change the physical, chemical, or biological characteristics of air, water, or land—affecting the health, survival, or activities of organisms and contributing to the forces that simplify and fragment communities and ecosystems.

Adverse Impacts to Surface and Ground Water Systems

Poorly managed construction sites and bare fields allow soil to wash off the land in runoff. This sediment can smother gravel riffles in a stream, destroying the habitat for aquatic invertebrates and spawning sites for some fish. Excessive organic waste flowing into a lake or stream uses up dissolved oxygen as it decays, which can kill aquatic life either through direct toxicity, destruction of habitat or food supplies, or by elimination of the dissolved oxygen needed by aquatic plants and animals. Phosphorus and other nutrients flowing off fertilized lawns and cropland into waterways may allow growth of excess algae and other aquatic plants. When large amounts of this vegetation die, decomposing bacteria use up dissolved oxygen, killing fish and other aquatic life.

Direct discharge of industrial effluent and sewage, which contain organic residues, chemicals, and sediments, can limit dissolved oxygen in the receiving water, otherwise change water chemistry, alter habitat, and kill organisms. Some chemicals present in industrial and municipal effluent, such as dioxin, have been shown to cause diseases, suppress the immune systems of a variety of species, harm reproductive capability, and produce genetic defects in offspring. The temperature of wastewater may also change normal aquatic temperature gradients and disrupt the life cycles of some aquatic plants and animals.

Pollution of ground water, caused by events such as gasoline leaking from underground storage tanks, nutrients leaching from inadequate septic systems, or pesticides washing off farm fields, poses a direct human health hazard when it reaches household water supplies. Contaminated ground water can also flow into streams and lakes, creating the same pollution effects as effluent that has directly entered surface water.

Adverse Impacts from Air-Carried Pollutants

There is increasing evidence that chronic exposure to certain levels of air pollution impedes the long-term survival and vigor of many species of plants. Trees in heavily polluted urban areas, for example, have a much shorter life span than trees of the same species in less polluted areas. In fact, some species of trees simply cannot grow in areas with severe air pollution. For example, high levels of ozone in the air of southeastern Wisconsin are known to limit the growth of several species of trees. Even at moderate levels of air pollution, some individuals within a population are genetically more sensitive to air pollution and will be eliminated from the population, resulting in simplification of the gene pool. This is a good example of reduction in genetic diversity. Neither the short-term nor the long-term implications of this simplification is understood at this time.

Acid deposition from air-carried pollutants may change water chemistry in some lakes, which in turn can change the diversity and abundance of aquatic organisms and communities. Acid deposition may change the pH of a waterbody, which can encourage the release of mercury already present in sediments or substrates. This process may enhance bioaccumulation of mercury, which accumulates in organisms at the top of the aquatic food chain, affecting their health, survival, or offspring.

There is limited but increasing evidence that mammals, birds, and other organisms are also adversely affected by inhaling airborne pollutants such as pesticides, heavy metals, and organic chemicals. If not directly toxic within an adult organism's life span, these substances may be toxic to an organism's progeny by causing birth defects, depressing the immune system, or changing the structure of DNA.

On a global scale, a build-up of carbon dioxide in the atmosphere from fossil fuel combustion may eventually affect climate and dramatically change ecosystems by causing global warming. Also, the release of chlorofluorocarbons and similar chemicals also depletes the ozone layer in the earth's stratosphere, thus exposing living things to harmful levels of ultraviolet radiation with potentially dangerous global implications.

Adverse Impacts to Land-Based Systems

Many land-based activities fragment or simplify ecosystems through pollution, either by direct effects such as an oil spill or through secondary impacts such as soil erosion from poor farming practices. Spills of hazardous materials can affect local areas by smothering animals or interfering with their movement. Improper disposal of hazardous wastes can result in local concentrations of metals or organic compounds that harm organisms and ecosystems. Pesticides and herbicides can kill nontarget species, changing the species composition in the area and weakening the ecosystems in which these organisms lived.

Land-based pollution also impacts other systems, most often surface and ground water systems. For example, an improperly functioning landfill may contaminate nearby soil and harm plants and animals living in the immediate area. However, leachate from the same landfill may also enter the ground water and contaminate lakes and streams miles away.

Implications of Ecological Issues

Our current understanding of ecosystems and, specifically, the implications of ecological simplification, fragmentation, and pollution present considerable opportunities and challenges to the Department's management programs. Present-day management strategies consider biological diversity mostly in a peripheral sense. Although awareness is increasing, overall program planning is not consistently based on the principles of ecosystem management. It is these principles that will allow us to address biodiversity within the context of ecological, socio-economic, and institutional concerns. These principles and their application to Department programs are fully discussed in the next section, "Addressing Biodiversity through Ecosystem Management."

While the main implication of the ecological issues is the need to implement ecosystem management, there are a number of related implications that are important to identify. First, staff will need the tools to determine the appropriate spatial and temporal scales as they plan and conduct their management activities. In the past, we have been most comfortable managing individual DNR properties on a short time frame (ten years or less), a scale at which we are able to observe immediate and obvious impacts, obtain the most information, and provide the most certainty. In the future, we will be managing at a larger scale, considering entire landscapes and much longer time frames, with less obvious immediate impacts.

One important tool that will help us think and plan on the landscape scale will be the delineation of *ecoregions*. Ecoregions are large areas of the state that exhibit similar patterns in potential natural communities, soils, hydrologic conditions, landforms, lithology, climate, and natural processes. Ecoregions provide a focus for resource assessment and inventory of biotic and abiotic elements. We need to determine the most useful boundaries for ecoregions within the state, and develop goals and management strategies for them. These will give us the framework needed to choose our priorities and focus our resources on carefully selected programs and projects.

We will also need data management techniques such as computerized *Geographic Information Systems* (*GIS*) to compile information on ecosystems and landscapes and to design process-oriented management approaches. These and other tools, such as a statewide aquatic and terrestrial inventory, will help us collect and manage the extensive amount of information needed to make decisions at a landscape scale.

The issues of ecological simplification, fragmentation, and pollution are not distinct issues that can be debated or weighed in isolation from each other. Like ecosystems themselves, these issues are often interrelated and complex. Ecosystem management focuses on evaluating the cumulative impact of proposed actions at the landscape level. At the same time, fragmentation and simplification may not always be bad. For example, the creation of

> This report proposes that the best way to address biodiversity as a management issue is to apply the principles of ecosystem management to Department planning and programs. Ecosystem management is a system to assess, conserve, protect, and restore the composition, structure, and function of ecosystems, to ensure their sustainability across a range of temporal and spatial scales, and to provide desired ecological conditions, economic products, and social benefits.

edge between habitats to enhance populations of game species is desirable in certain locations within the landscape. The important thing is to recognize the complex impacts of our proposed actions (how much edge is desired and where should it be?), to clarify why they are desirable, to know the trade-offs, and to try to understand their impacts on ecosystem sustainability and, especially, on our options for the future.

Because our understanding of the ecological issues is constantly increasing, we can use our current understanding to make decisions to implement now and then adapt as we learn more. One approach that we will need to explore is currently known as *adaptive management*. Adaptive management considers many alternate management scenarios developed collaboratively by scientists, managers, and policy makers. Models are then developed to predict the results from each management alternative, management prescriptions are subsequently chosen, and monitoring programs are designed to scientifically test whether the management alternative does indeed accomplish the predicted results. In this way, the management practice enhances the "institutional memory" that documents our decision-making process while continually improving the science base for our management practices and advancing our knowledge of ecosystem functions.

Because the focus of this report is on the management of public lands, we do not propose specific recommendations for how the Department's regulatory programs might change to address the conservation of biodiversity. However, because pollution can seriously affect the biodiversity of a variety of aquatic and terrestrial communities, in the long run we must consider how the science of biodiversity can be incorporated into the regulatory and technical assistance work of DNR's environmental quality programs.

Addressing Biodiversity Through Ecosystem Management

What is Ecosystem Management?

To understand what the conservation of biodiversity will mean to the Department's management system, we must understand ecosystem management as the philosophy and process we will be using in the future. *Ecosystem management* is a system to assess, conserve, protect, and restore the composition, structure, and function of ecosystems, to ensure their sustainability across a range of temporal and spatial scales and to provide desired ecological conditions, economic products, and social benefits.

The above definition reflects the complexity that the ecosystem management "umbrella" is meant to encompass. What does it really mean? In simpler terms, ecosystem management blends human needs and values with ecosystem capability and sustainability (Fig. 7). This blending of multiple perspectives is essential to making wise choices about how resources will be managed to result in an agreed-upon pattern of land uses. This pattern will be a mosaic of cities, towns, and suburbs; parks, lakes, wetlands, and forests; farms and industries; natural areas and reserves; and corridors and riverways.

The landscape pattern that is desired will be defined over time as we work with multiple interests and partners in decision-making. This report proposes that we make a commitment to the **principles and processes** of ecosystem management and fully develop within that commitment the goals and criteria that will be needed to conserve biodiversity as an essential element of ecosystem sustainability.

In listing these principles and processes, it may be helpful to think of them in the following two categories: Ecosystem Approaches and Critical Thinking Skills.

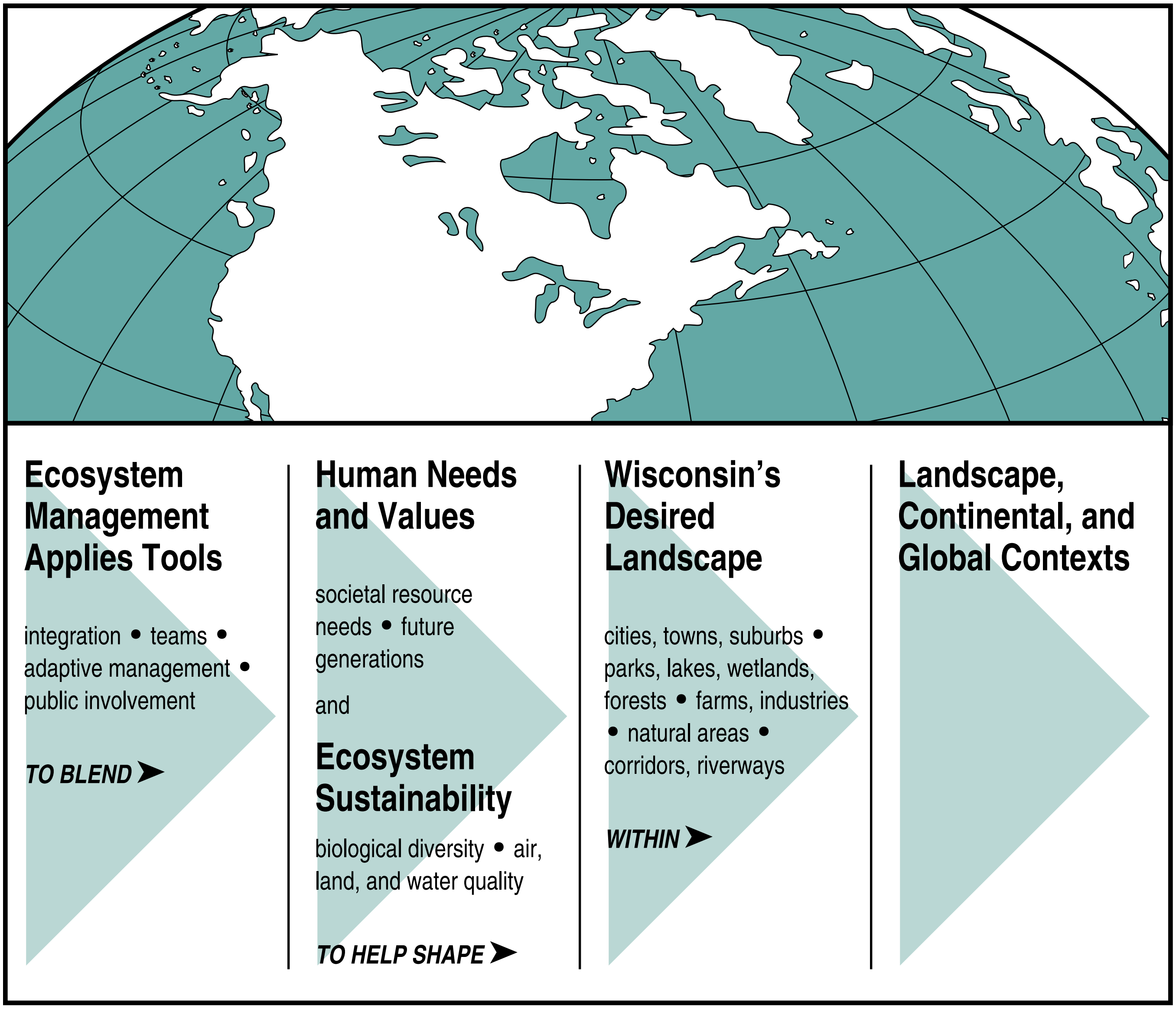


Figure 7

The processes and components of ecosystem management.

Ecosystem Approaches

Management goals should be set and action taken using an ecosystem management approach that integrates staff and resources across programs and disciplines. Current statutory charges were developed to manage single species or small assemblages of economically important species. However, biological diversity is not, and should not be treated as, a separate organizational subprogram. Rather it will be included within the entire range of issues that DNR managers must consider when they carry out the agency mission.

▲ **Determine ecoregion boundaries and use them to develop management goals.** Set goals within ecoregions to meet a wide variety of diverse ecological and socio-economic needs, including the conservation of biodiversity.

▲ **Manage to preserve ecological composition, structure, and function.** Consider not only immediate impacts but also the dynamics of long-term changes induced by proposed management actions.

▲ **Manage at a landscape scale.** Determine both spatial and temporal scales appropriate to a problem or project. Assess the impacts of decisions made at any one scale on both smaller and larger scales.

- **Incorporate a *transdisciplinary perspective*.** Develop and support a diverse staff with a working knowledge of a wide range of disciplines and a willingness to integrate those disciplines in innovative ways. New ways of working together will transcend the limitations posed by traditionally separate disciplines. Managers working in integrated teams will form the foundation for the way we "do" ecosystem management.

- **Find ways to take action without "knowing all the answers."** Use a management approach that can be applied now while allowing us to continually increase our understanding of ecosystems and adapt our practices as we learn more. Used within an ecosystem management approach, the adaptive management approach described earlier can help us do this in a formal and structured way.

Critical Thinking Skills

Employees and the public must be encouraged to take responsibility for examining their own knowledge and beliefs. Commitments to solutions that treat problems, not just symptoms must also be encouraged. This will require that we foster *critical thinking* skills. Critical thinking is a process of reflection and analysis that involves the identification of assumptions and known facts, the exploration of alternatives, and the integration of new understandings into thought and behavior patterns. For example, in order to support critical thinking, we must:

- **Provide DNR employees and the public with training and awareness opportunities.** Prepare staff to lead the public dialogue that will produce a clear and widely accepted understanding of biodiversity and decisions that we can collectively support and implement in our day-to-day living.

- **Lead the discussion clarifying public values related to biodiversity and the environment.** Continue to bring diverse interests together to discuss and resolve the issues. Work to anticipate problems, manage conflict, and avoid the kinds of confrontations between conflicting interests that have occurred in other states.

- **Act on a vision of biodiversity that is grounded in scientific fact, clarified values, and hard-nosed realism.** View projects that aim to conserve biodiversity with the same scientific rigor that we view those to develop the landscape for other human needs. Be responsive to the role that values play in exploring alternative solutions to problems and in selecting final approaches.

We won't be able to implement all of the recommendations and possible actions in this report at once. We will need to set realistic priorities and clear course of action that provides a roadmap for DNR staff and our partners and clients.

Using Ecosystem Management Routinely

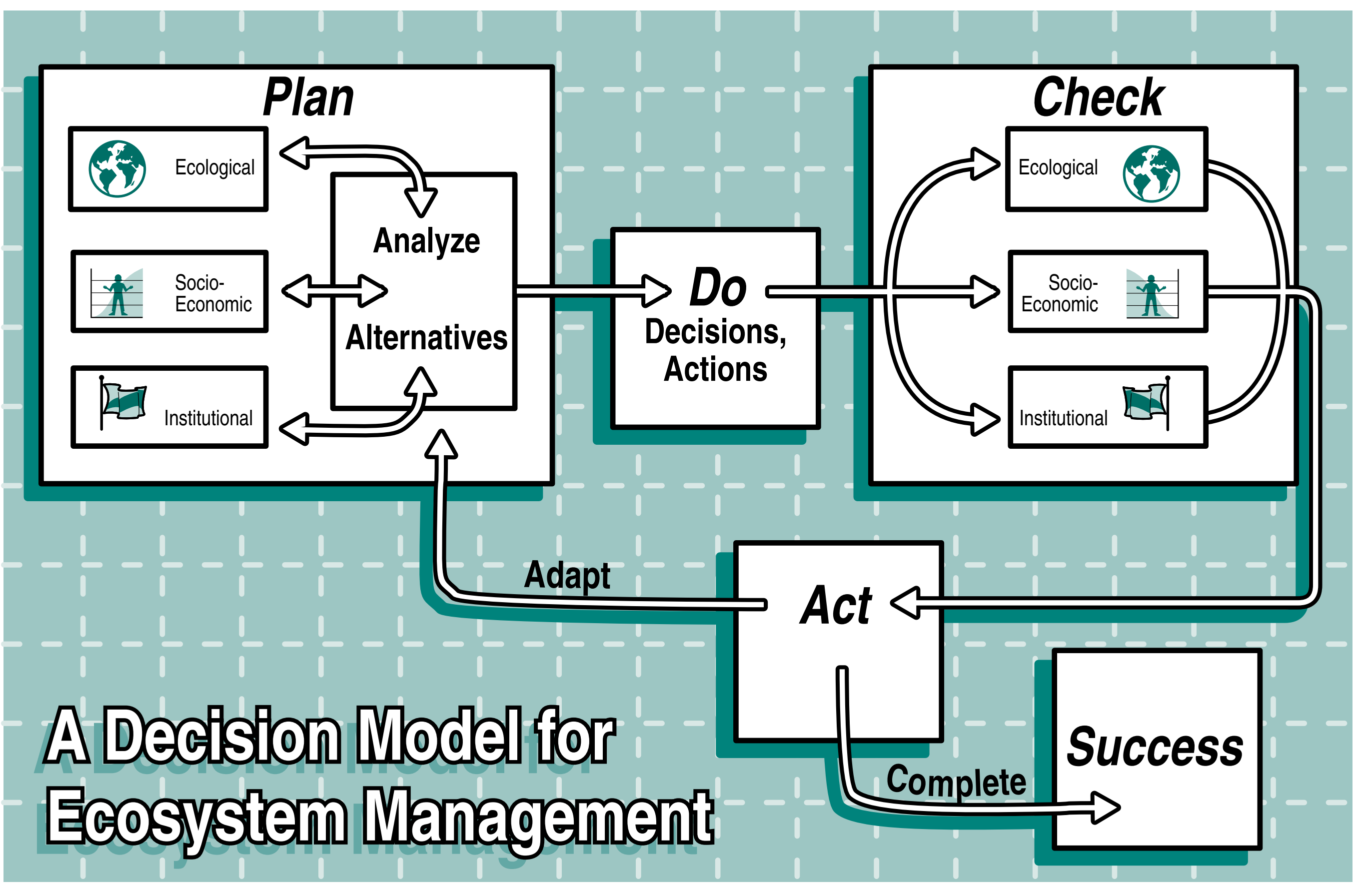
We will be expected to apply the principles of ecosystem management on a daily basis. Some aspects of ecosystem management are familiar to DNR managers, many of whom have been thinking in terms of ecosystems and integrated approaches for many years. Many of the procedures required to conserve biodiversity are already included in our "toolboxes," and others need to be invented. Whether the ideas are familiar or new, all managers will have questions about how to use ecosystem management principles in daily work and how to meld these comprehensive management approaches with traditional management activities. They will ask questions like: "How much restoration can we do?," "How should we view active management practices like fish-stocking and clearcutting?," "How can we reconcile biodiversity with user demands?," "How does ecosystem management consider the needs of humans as well as the needs of all other species?” The answer to each question depends on the specific circumstances or context in which it is asked. For example, a decision to restore a damaged community is appropriate in some situations but inappropriate (or impossible) in others. Similarly, a decision to stock fish may fulfill a user demand at the expense of native species, or it may replace a missing predator and restore balance to a lake’s ecosystem. The appropriateness of any management practice or environmental decision depends on its context. There are no easy answers or “cookbook” formulas for management practices that will always conserve biodiversity. Rather, we must use a management model that brings perspectives and knowledge from different disciplines together in an integrated search for alternatives.

The ecosystem management decision model shown in Figure 8 provides a framework that requires us to approach decision-making from different perspectives. By examining several alternatives relative to their consequences in ecological, socio-economic, and institutional contexts in the PLAN phase, the model holds that we will make wiser management decisions. Whatever alternative we decide to implement (DO) is then monitored (CHECKED) for its actual results in all three contexts, and we revise our management (ACT) according to those results. Our success as resource stewards is a function of our ability to understand, analyze, and integrate alternatives across all three of these contexts.

The ecosystem management decision model presents a structured approach to the search for solutions that integrate ecological, socio-economic, and institutional concerns.

Figure 8

An ecosystem management decision model.



The Ecosystem Management Decision Model

The ecosystem management decision model is based on an examination of questions and considerations within each of three contexts: the ecological, socio-economic, and instituional:

The Ecological Context

Defining and subsequently managing in an ecological context is both an art and a science. As our understanding of ecological concepts grows, as our body of ecological theory and scientific evidence is enriched through time, and as our measures of the impact of various decisions on the ecosystem become more predictable and precise, our ability to identify and make informed ecological choices will increase.

Depending on the ecosystem and the management issue, a variety of considerations are used to establish the ecological context. The process of determining the ecological context begins with a definition of scale, followed by an assessment of the system's *capability* and function.

Scale

Question: *At what spatial and temporal scales should the decision be defined?*

Some considerations:

- ✓ size of the affected system and its parts
- ✓ current inventory of what is there now, including measures of biological diversity
- ✓ species with critical needs or special status
- ✓ presence of ecological gradients and corridors
- ✓ patterns of community distribution
- ✓ existing patterns of disturbance or change
- ✓ current management practices, land use, and land ownership

Capability

Question: *What is the system's past, current and potential future ecological capability; where is the landscape headed?*

Some considerations:

- ✓ natural and potential capability (e.g., presettlement vegetation as one indicator)
- ✓ history of successional stages
- ✓ potential for recovery, enhancement, or expansion
- ✓ potential to be self-sustaining

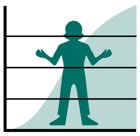
Function

Question: *How can we improve or protect the system's function? How well is it working now?*

Some considerations:

- ✓ interrelationships between the abiotic and biotic components—missing components (composition, structure)
- ✓ connectivity
- ✓ fragmentation
- ✓ resilience
- ✓ gene flow
- ✓ energy and nutrient flow
- ✓ food webs

THE SOCIO-ECONOMIC CONTEXT



The Department also manages in a socio-economic context that reflects the varied and sometimes conflicting needs and values of people. Our mission requires us to be responsive to society, yet it recognizes that our decisions also help to shape society's values. Furthermore, our actions have direct impacts on the economy at the local and state levels, and beyond. Our decisions are evaluated within this socio-economic context, and society determines our success or failure. As we work with stakeholders to understand their views and values, we also need to understand the impact of management activities on local business, land values, and other economic factors, including a view of long-term economic perspectives.

We can understand the socio-economic context by knowing the stakeholders and the range of economic issues they represent.

SCALE

Question: *At what spatial and temporal scale should the decision be defined? What is the magnitude of social and economic effects?*

Some considerations:

✓ number of people affected, directly and indirectly
✓ cost and funding for the project
✓ time period for completion
✓ time period of social or economic impacts
✓ scope of social or economic impacts (local, state, regional, national, international)

LAND USE

Question: *What are the past, present, and potential land uses?*

Some considerations:

✓ current and previous land uses
✓ projected changes in land uses
✓ alternative future land uses
✓ indirect effects on adjacent or regional land uses
✓ land ownership patterns

ECONOMIC IMPACTS

Question: *What are the opportunities and threats for business and employment?*

Some considerations:

✓ direct and indirect impacts on local and state businesses
✓ potential new businesses created
✓ impact on current and projected property values
✓ impact on employment
✓ sources of raw materials or other resources for business
✓ relationship to transportation or utility networks
✓ relationship to national and international economy

STAKEHOLDER INTERESTS

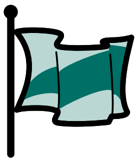
Question: *Who are the stakeholders and how can they best be involved? What are their various perspectives, needs, and values?*

Some considerations:

✓ major and minor stakeholders (public and private)
✓ role of elected officials
✓ public involvement and information strategies
✓ relationship of stakeholders to DNR and to each other
✓ opportunities for partnerships with stakeholders

The Ecosystem Management Decision Model, cont'd

The Institutional Context



As an institution, the Department operates within a matrix of complex institutional relationships. First, the Department's actions must be based on sound legal authority. This authority is defined by state constitution, state and federal statutes, administrative rules, and court decisions. Second, Department actions are also affected by internal policies and by budgets, staffing, and various authorities granted to the agency. Management actions that do not fit within this external or internal institutional framework or authority are either not feasible or require changes in our laws, codes, or mission. And third, the Department has many opportunities to create cooperative agreements and partnerships with other public and private institutions, as well as with individuals, in order to meet mutual goals for resource protection, restoration, or enhancement.

Legal Framework

Question: *What institutional support or constraints come from outside DNR? What is DNR's legal relationship to local, state, and federal governments?*

Some considerations:

✓ legal authority (statutes and administrative rules)

✓ legal constraints

✓ processes for obtaining decisions from appropriate authority (local government, legislature, federal agencies)

✓ need for new legal authorities or changes in existing laws

✓ state budget development, federal grants, etc.

Internal DNR Policies:

Question: *What internal policies or procedures support or hinder a proposed action?*

Some considerations:

✓ strategic plans

✓ budget and staffing

✓ manual codes and handbooks

Interagency Cooperation and Private Partnerships

Question: *What kinds of relationships with other public agencies or with private interests are needed?*

Some considerations:

✓ existing and potential partners and cooperators

✓ institutional constraints of partners and cooperators, such as their ability to enter into long-term agreements

✓ innovative approaches to cooperation and partnership

Is this model all that new? Many parts of the model are not new, in that they represent the way many managers have thought and acted for years. The Department has conducted a number of planning efforts that are based on watersheds or other ecological units and have dealt with a range of socio-economic and institutional issues. Examples are the Green Bay Remedial Action Plan, the Winnebago Pool Integrated Resource Management Plan, the Milwaukee River Integrated Resource Management Plan, and the Mississippi River Strategic Plan. There are other examples cited as case studies within the following chapters on Wisconsin's biological communities. These include projects related to the Baraboo Hills, Marathon County Forest, Habitat Restoration Area (formerly Glacial HRA), Southern Unit Kettle Moraine State Forest, and Patrick Lake wetland mitigation.

What is new is putting all the parts together and using them throughout the Department as a decision framework. Also new is the importance of considering multiple levels of scale in all decisions. While some managers already do this, we need to work together to do it consistently, with attention to all contexts of the ecosystem-management decision model.

Success lies in carefully considering all three context—ecological, socio-economic, and institutional—and finding an alternative that is acceptable in all three. We cannot only consider the ecological context in making management decisions. The "correct" ecological decision may be impossible or unworkable given the realities of our society, the economy, and the institutions in which we work. Similarly, the "best" economic decision may be ecologically disastrous. Our hope is to provide an open public process in which social, economic, and ecological perspectives are evaluated and weighed early on—before positions become hard and fast. It is, in reality, a search for acceptable alternatives that help preserve long-term options and improve the quality of our everyday lives and the lives of the generations to come.

Recommendations

Implementing ecosystem management in Wisconsin requires concrete actions. The following recommendations are the product of review by and dialogue with internal DNR staff and external partner agencies, scientists, interest groups, and citizens. The recommendations are put forth to begin the process of working with the Natural Resources Board and all our partners and customers to outline the details of specific actions needed. As we move forward, we will need much more discussion, both internally and with the public.

1 ***Apply ecosystem management principles and practices to the Department's programs so that goals and priorities for biodiversity can be determined in the context of ecological, socio-economic, and institutional issues.***

- Use the ecosystem management decision model, as described in this report, to propose and evaluate alternative actions from the ecological, socio-economic, and institutional perspectives.

- Develop and use ecoregion goals and objectives to design and implement geographically-based management guidelines. These procedures will provide the criteria needed for:
  - ✓ land acquisition priorities
  - ✓ new and revised master plans for state-owned property
  - ✓ priorities for restoration of biological communities
  - ✓ use of appropriate genotypes in restoration and management
  - ✓ management of populations of troublesome non-native species
  - ✓ goals for consumptive use, such as harvest of forest products, fish, and wildlife

- Continue to develop a Geographic Information System (GIS) as a major management tool needed to implement ecosystem management and to establish and evaluate ecoregion goals and objectives. Train staff to use GIS to analyze and monitor regional landscapes.

- Continue to develop and use a statewide resource inventory of the status and distribution of aquatic and terrestrial species, biological communities, and other attributes within the ecoregions of Wisconsin.

- Use the biennial budget guidance to address management priorities and goals for ecosystem management.

- Review existing laws and procedures to analyze their consistency with the principles of ecosystem management. Modify them where necessary. This will be a formidable task, since our procedures are embodied in a multitude of handbooks and guidelines. However, these procedures must be consistent and must work for, not against, ecosystem management and the conservation of biological diversity.

- Monitor and respond to ecological, socio-economic and institutional issues as they develop. Examples of current issues that arise in the ecological context include the role our management actions may play in ongoing fragmentation and simplification, the need for prescribed burning as a management tool, and the desire to manage for the range of successional stages of each major community type.

- Employ both research and experimental management to develop new management approaches and to refine existing ones. These efforts should be directed at expanding our understanding of ecosystems and clarifying options for future management.

2 ***Build partnerships with other agencies, local governments, tribes, the business community, scientists, and other interest groups to accomplish common goals for ecosystem management, including specific attention to biodiversity.***

- Seek innovative ways to work with partners to set landscape-scale goals that cross ownership boundaries.

- Continue to participate in joint efforts such as the 1994 Wisconsin Forest Accord (a memorandum of understanding to adopt uniform criteria to describe, evaluate, and share critical ecological information among private landowners and nonprofit, county, state, and federal agencies) and the Interagency Cooperation on Ecosystem Management or ICEM (a multi-agency resolution forming a consortium of 20 Midwestern state and federal agencies, including Wisconsin's DNR, working together to coordinate ecosystem management activities).

- Take advantage of the knowledge and capability of the scientific community in reviewing how we apply scientific knowledge to our management strategies.

- Seek input from business and economic interests to develop strategies to implement ecosystem management.

- Work with hunting and fishing groups to use the principles of ecosystem management to improve the quality of hunting and fishing in Wisconsin.

- Encourage and support efforts at the national level to screen proposed introductions of non-native species.

3 ***Build partnerships with private landowners to accomplish common goals for ecosystem management, recognizing that the Department cannot accomplish the breadth of what needs to be done to conserve biodiversity by working on public lands alone.***

- Establish coalitions and partnerships with private landowners to protect and restore biological diversity.

- Provide technical assistance, economic incentives, and education to encourage private landowners to participate in the conservation of biological diversity.

4 ***Develop innovative and proactive information and education strategies for Department staff and the public regarding biodiversity and its relation to ecosystem management.***

- Create ecosystem management demonstration areas in each ecoregion that invite hands-on participation and illustrate applied ecosystem management and biodiversity concepts.

- Design approaches to outreach and training to increase understanding of ecosystem management and to clarify the variety of professional and personal values regarding biodiversity.

- Provide support to employees to increase their skill in bringing diverse groups of people together to discuss and resolve issues related to ecosystem management and biodiversity.

5 ***Set priorities for implementing the possible actions specific to each of Wisconsin's seven biological community types described and assessed in the remaining chapters of this report.*** These possible actions are described in detail at the end of each of the seven biological community chapters. We call these "possible actions" because they are consistent with ecosystem management but require more analysis and planning. The following possible actions are consistent with ecosystem management, but require more analysis and discussion. How priorities are set within this list will be based on ecoregion goals, staff workload, fiscal resources, public input and support, and legal authority. We will work with our customers and clients to set priorities and bring recommendations to the Natural Resources Board for consideration beginning in the 1995-97 biennium.